<u>RTCA Special Committee 186, Working Group 3</u>

<u>ADS-B 1090 MOPS, Revision A</u>

<u>Meeting #12</u>

Preamble Detection, Lincoln Laboratory Design

Presented by William Harman

SUMMARY

This paper provides a description of the preamble detection process being used at Lincoln Laboratory. Much of the description is already included in the MOPS in Appendix I, in the original form (in DO-260) and in the updated form, which is available at the Tech Center web site. But this paper gives a stand-alone description of the whole process, including additional detail, so that any differences between the Lincoln Laboratory version and the Tech Center version can come to light.

Preamble Detection, Lincoln Laboratory Design

William Harman

Preamble Detection is a process that identifies the beginning of an Extended Squitter reception. The outputs are (1) the start time of the signal, (2) the received power level of this signal. This process includes validation which uses the receptions during the first 5 bits in the datablock and several other validation tests. The preamble detection process in the Lincoln Laboratory design is defined in detail in this working paper.

Most of this definition is already documented in the Ext. Sq. MOPS, DO-260, Appendix I, but a more complete definition is given here.

Threshold. The process includes a threshold power level set by the designer used to discard very weak receptions. Typical value = -88 dBm (referred to the antenna) for an A3 receiver. MTL, which is the point of 90 percent receptions in the absence of interference, is typically about 4 dB higher than the threshold.

Leading Edge. A "Leading Edge" is declared for a particular sample if it is a "Valid Pulse Position" (defined below) and also has slope before and non-slope after. Slope is defined by the power change between one sample and the next. The slope threshold is 48 dB per microsec. Therefore if the sample rate is 8 samples per microsecond, the threshold is 6 dB. For 10 samples per microsecond the threshold is 4.8 dB.

Valid Pulse Position. A sample that is above threshold, and also is followed consecutively by N or more other samples above threshold. For 8 samples per microsec., we use N = 2. If the sample rate is 10 samples per microsecond, as in the Tech Center design, N = 3. More generally, N = S/2 -2.

In other words, for a pulse to be declared requires at least 3 consecutive samples above threshold for 8/microsec., and at least 4 consecutive samples above threshold for 10/microsec.

In my opinion, the term "Valid Pulse Position" is somewhat confusing, because the word position seems to indicate sample time rather than the signal received at that time. Another possible name for this might be a "Front Pulse Sample".

Initial detection of a 4-pulse preamble. The process begins when 4 pulses have been detected, having the spacing of the Mode S preamble. The detection criterion is:

- Finding 4 pulses, spaced by 0-1-3.5-4.5 microsec.
- 2 or more of these must be Leading Edges.
- The others can be "Valid Pulse Positions"
- Sample tolerance can be plus or minus 1 (but not both)

Note that the power levels need not agree. Note also that trailing edges are not used.

Time. The signal start time is initially estimated by the leading edge of the first of these 4 pulses. But this is adjusted by +1 or -1 if two or more of the other three pulse have leading edges with that timing.

Reference Level Generation. A Reference Power Level is generated during preamble detection for use in retriggering and during demodulation of the datablock. Step 1 is to identify a set of samples to use. For the four preamble pulses, identify which have leading edges that agree with the preamble timing, and limit the samples to these pulses. Then select the M samples after the leading edge sample, and enter these into the reference level generation algorithm. For the Lincoln design using 8 samples per microsec, M = 2. For the Tech Center design using 10 samples per microsec., M = 3.

Step 2 is an algorithm to generate the Reference Level from these samples. For each sample, compute the number of other samples that are within 2 dB. Then find the maximum of these counts. If the max. count is unique, then the sample used to form that count is taken to be the Reference Level.

Otherwise, when there are two or more samples whose counts are maximum and equal, discard any samples whose counts are less than this maximum. For the remaining samples, find the minimum power and then discard any samples that are more than 2 dB stronger than that minimum. Compute the average of the remaining samples. This is taken to be the Reference Level for that preamble.

Overlapping signals and retriggering. The above description applies to an initial preamble detection. It's possible that overlapping signals might be received, and provisions have been made for that. The preamble detection process is capable of detecting multiple overlapping preambles, but the datablock processing can only accept one signal at a time (because the computations are more extensive). Therefore a retriggering function is included, which will reject certain preamble detections when a subsequent stronger signal is received.

One step in the retriggering process checks for overlap by later Mode S signals having certain specific timing offsets. For example, if the subsequent signal is 1 microsecond later, then two of the preamble pulses in the later signal coincide with preamble pulses in the original signal, which can cause a problem if the later signal is stronger. The problem is that the stronger pulses can cause the power estimate for the first signal to be too high, and therefore prevent retriggering. This type of problem can also occur if the timing difference is 3.5 or 4.5 microseconds.

The 1-microsecond test. To counter this problem, the next step after preamble detection is to check for excessive power in pulse positions 1, 2, 4.5, and 5.5 microseconds after the start. For each of these pulse positions, one sample is used to estimate the power of a pulse at that time. Letting T = 0 denote the time one sample after the leading edge time of the first preamble pulse, then the four pulses are taken to be the samples at times T = 1.0, 2.0, 4.5, and 5.5 microseconds. From these four power measurements, the minimum is used to compare against the maximum of the samples at T = 0 and 3.5 microseconds. If this difference indicates that the preamble under consideration is weaker by 3 dB or more relative to the other four samples, then this preamble is rejected. Figure 1 illustrates the 1 microsecond overlap that motivates this test.

The 3.5-microsecond test. A similar test is performed to protect against overlap by a stronger signal 3.5 microseconds later. The minimum power in samples at T = 3.5, 4.5, 7.0, and 8.0 is compared against the maximum of the samples at T = 0 and 1.0 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

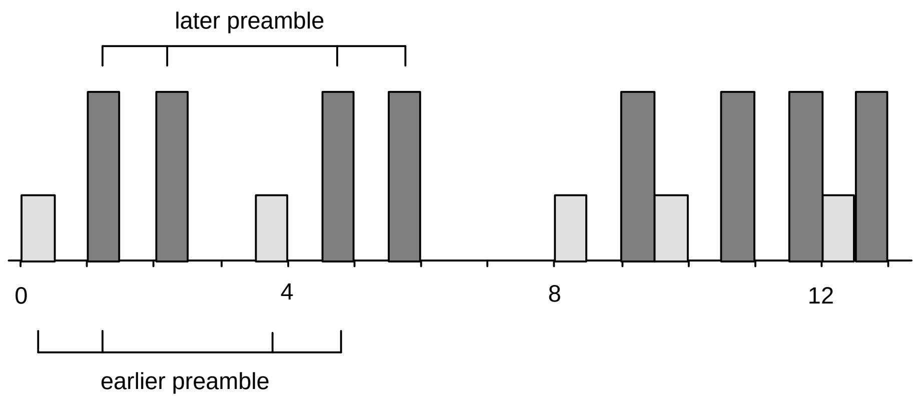

Figure 1. Overlap of a weak signal by a later and stronger signal.

The 4.5-microsecond test. A similar test is performed to protect against overlap by a stronger signal 4.5 microseconds later. The minimum power in samples at T = 4.5, 5.5, 8.0, and 9.0 microseconds is compared against the maximum of the samples at T = 0, 1.0, and 3.5 microseconds. If this difference indicates that the preamble under consideration is -3 dB or weaker relative to the other four samples, then this preamble is rejected.

After a preamble has been discarded by one of these tests, the preamble detector is free to trigger on a stronger signal received a short time later.

Consistent Power Test. Another test is applied to validate the preamble. This test asks whether at least two of the four preamble pulses agrees with the Reference Level to within +/-3 dB. If not, this preamble is rejected.

DF Validation is done using the reception during the first 5 bits in the datablock. Pulse detection is carried out for the 10 chips as follows. For a particular chip, a pulse is detected if a Valid Pulse Position is found at the leading edge time for this pulse or within +/-1 sample of the leading edge time. Then the preamble is validated if, for each of the five bits, a pulse is detected either in the first chip or in the second chip or both. Otherwise the preamble is rejected.

Conceivably this test could be applied using either the original receiver threshold or a dynamic threshold making use of the Reference Level. In the current Lincoln design, which has been modified in recent months based on advice from John Van Dongen, a dynamic threshold is used, which is 10 dB below the Reference Level.

Retriggering. After a preamble is detected, the detection process continues to be applied searching for later preambles. All of the steps described above are applied even when detected preambles are overlapped. If a particular preamble detection has survived these validations tests, its reference level is now compared against any earlier signal currently being processed. If the new signal is stronger by 3 dB, then the earlier signal is rejected, so that datablock demodulation of the new signal can proceed. Otherwise, if an earlier signal is being processed and the new signal is not stronger by 3 dB, then the new signal is rejected, so that the earlier signal processing can continue.

Summary. Figure 2 summarizes the preamble detection process.

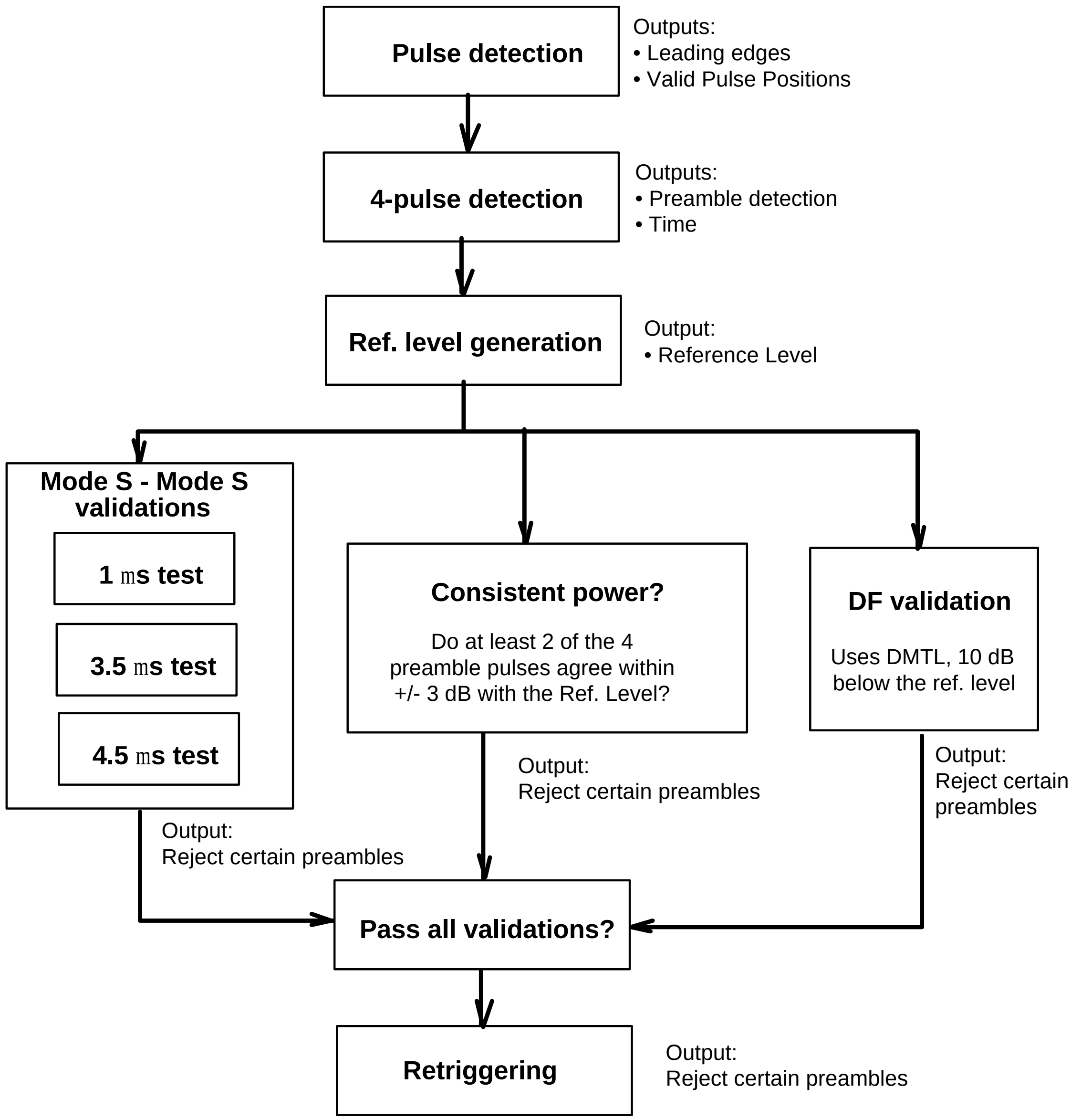

Figure 2. Overview of Extended Squitter Preamble Detection.